GRANITIC REGOLITH AND LANDSCAPE EVOLUTION OF WILSONS PROMONTORY, VICTORIA

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The granitic regolith and associated landscape features at Wilsons Promontory have evolved from a major period of deep weathering that occurred since the Devonian, probably after the widespread Permian glacial erosion. During these times of relative tectonic stability and subdued topography, conditions were conducive to the accumulation of weathering products in deep profiles with minimal erosion of this material. Topographic relief and tor morphology considerations suggest the existence of a single weathering profile at least 300 m deep. Tectonic instability since the mid Cretaceous led to faulting and associated uplift of much of the Wilsons Promontory area, instigating the stripping of the deep weathering profiles. The progressive stripping of the deep weathering profile is reflected in the derived sedimentary record. Remnants of deep weathering profiles and related palaeosurfaces are found in areas where the influence of erosion has been limited, such as in downfaulted areas in the interior of the highland ridges. Mobilisation of regolith materials in the Late Cenozoic has occurred in debris flows and outwash fans which now mantle many of the lower slopes and adjacent lowlands. Marginal marine and aeolian sand deposition, largely derived from the granitic weathering products, has occurred during the Late Cenozoic.

SINCE the nineteenth century Wilsons Promontory has attracted investigators from many of the branches of natural science, in particular the biological and earth sciences. Geologists have mostly focused on aspects of the Cenozoic sedimentation (e.g. Tuddenham 1970; Oyston 1988) or the geological features associated with the igneous petrology of the Devonian Wilsons Promontory Batholith (e.g. Wallis 1980, 1981, 1988; Carson 1990). None of these studies has made a detailed examination of the landscape evolution which is the topic of this paper.

Wilsons Promontory, the most southerly point of the Australian mainland, lies approximately 230 kilometres southeast of Melbourne, Victoria. Most of Wilsons Promontory and adjacent islands are located within Wilsons Promontory National Park and Commonwealth land associated with the lighthouses at South East Point, and Citadel Island in the Glennie Group (Fig. 1).

GEOLOGICAL SETTING

Wilsons Promontory consists of granite from a high level, composite body of S-type intrusives (Wallis 1981, 1988). Richards & Singleton (1981) showed the batholith to be Late Devonian, with a K-Ar age of 379 ± 15 Ma. Wallis (1980, 1981, 1988) distinguished seven main granitic members based on differences in modal mineralogy, bulk rock geochemistry and textural characteristics. The most distinctive differences between the members are in the modal percentages of K-feldspar, plagioclase and biotite. The Promontory Leucogranite (>38% K-feldspare, <17% plagioclase and <5% biotite) and the Xenolith Biotite Adamellite (<30% K-feldspar, >25% plagioclase and >12% biotite) represent the compositional extremes. The internal geometry of the batholith is dominated by shallow (0–40°) easterly diping sheet-like granitic bodies which outcrop as elongate NNW–SSE trending zones (Wallis 1981, 1988).

The country rocks intruded by the Wilsons Promontory Batholith are Late Ordovician (Gisbornian) tightly folded sandstones and shales, as can be seen at the intrusive contact at Red Bluff near Yanakie. The batholith is flanked by Mesozoic and Cainozoic sediments of the Gippsland and Bass Basins. The sediments and tectonic structures within these basins relate to the continental rifting of Gondwana (Etheridge 1988; Duddy & Green 1992), when Australia was separated from Antarctica to the south and the Lord Howe Rise—New Zealand to the east.

Cenozoic sedimentary deposits within the area include Late Pliocene—Pleistocene terrestrial gravels equivalent to the Haunted Hills Formation (Hocking 1988). These ocur in the Corner Inlet area where they consist of ferruginous, well-rounded pebbles of quartz, chert and sandstone

(Oyston 1988). Marginal marine and aeolian sand deposits in the lowlands and along the coastal margins of Wilsons Promontory range from the Late Pliocene to the present (Tuddenham 1970; Oyston 1988). Active coastal sedimentation at Wilsons Promontory is characterised by the deposition of siliceous sands along the east coast and calcareous sands along the west coast. The calcareous sands are derived from submarine calcareous ridges to the west (Tuddenham 1970). Old siliceous sands in areas of the west coast (such as at Leonard Bay and Little Oberon Bay) represent sedimentation that occurred before the Yanakie Isthmus was developed and became a barrier to the movement of further siliceous sands from the east (Oyston 1988).

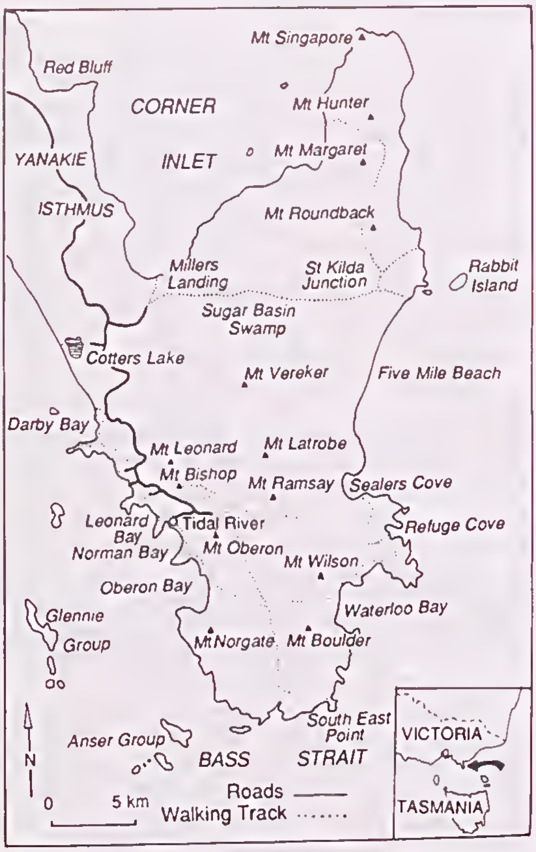


Fig. 1. Location map of the Wilsons Promontory area showing some of the sites mentioned in the text.

GENERAL GEOMORPHIC SETTING

Wilsons Promontory consists of a series of ridges of granitic highlands with adjacent low-lying areas of Cenozoic sediments. A major granitic ridge runs approximately north–south along the centre of the Promontory. This ridge contains the major peaks of Wilsons Promontory: Mt Boulder, Mt Wilson, Mt Ramsay, Mt Vereker and the highest peak Mt Latrobe (754 m). These major peaks are separated by a series of saddles. A major pass occurs between Mt Wilson and Mt Boulder, where an east–west trending valley runs the width of the Promontory between Oberon and Waterloo Bays. Branching from this central highland area are a series of smaller east–west ridges which terminate as prominent coastal headlands. The intervening bays and coves represent submerged valleys and lowlands.

The northeastern part of Wilsons Promontory consists of another north–south trending granitic ridge, forming the core of the Singapore Peninsula. This ridge contains the peaks of Mt Singapore, Mt Margaret and Mt Roundback, and rises to 347 m at Mt Hunter. A low east–west trending ridge connects the main highland ridge and the ridge of the Singapore Peninsula, between Sugar Basin Swamp and St Kilda Junction (Fig. 1). A mostly submarine north–south trending granitic ridge also occurs approximately five kilometres off the west coast of Wilsons Promontory. Exposures of parts of this ridge from north–south trending elongate islands such as within the Glennie Group.

In many areas the granitic highlands abut sandy lowlands consisting of outwash from the granitic highlands and associated aeolian and marine deposits. A low sandy area with large transgressive dune systems, known as the Yanakie Isthmus, joins the northwestern part of Wilsons Promontory to the mainland (Fig. 1).

THE GRANITIC REGOLITH MATERIALS

'Granitic regolith' here refers to all of the weathering products and associated transported material derived from the granite rocks. The weathered material which still retains the structures of the original rock is termed saprolite. In the upper levels of the weathering profile this material becomes disrupted, constituting what is termed the mobile zone. Fig. 2 shows some of the typical features of granitic regolith profiles. The granitic regolith materials at Wilsons Promontory can be subdivided into two major categories: in situ granitic weathering material (or saprolite and corestones)

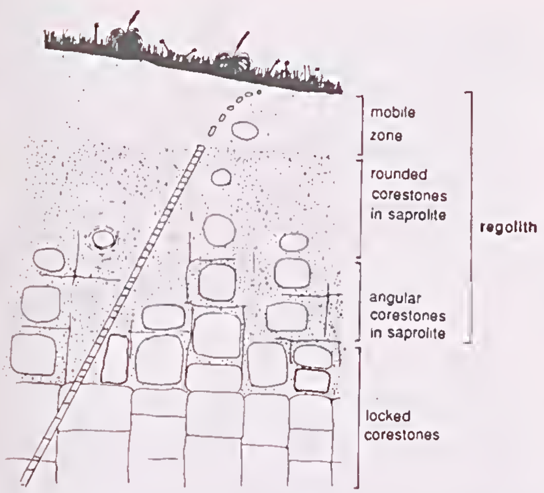


Fig. 2. Characteristic features and zones of a typical deep granitic weathering profile (after Ollier 1984).

and granitic material (both fresh and weathered) which has been mobilised downslope.

In situ granitic weathering material

The in situ material consists of saprolite often containing corestones of fresh granite, which may form tors as a result of erosion of the softer saprolite.

X-ray diffraction, Scanning Electron Microscope and thin section investigations (Hill 1992) reveal the mineral composition of the saprolite to be dominated by secondary minerals (particularly kaolinite, mostly derived from feldspar alteration) and resistant minerals (particularly quartz and minor tourmaline). Corestones may be of both the angular and rounded type depending mainly upon their relationship to zones within the weathering profile (Fig. 3).

Areas of in situ weathering material are mostly restricted to the interior of the central highland area where they have been protected from the

Fig. 3. Exposed section through the Little Oberon Bay debris fans looking south along coastal cliffs at southern end of Little Oberon Bay Beach (north end of Oberon Bay). Note the large boulders of fresh granite at the base of the cliffs which have been transported by the debris flows.

influence of erosive stripping. Some of the best exposures of in situ weathered granite can be seen in cuttings along the Wilsons Promontory Road and Mt Oberon Road and in the quarry on the lower slopes of Mt Oberon (Hill 1992). Stripping of much of this material from westerly and southerly exposures has been due to their exposure to the prevailing direction of wind, rain and coastal swells. These agents directly contribute to stripping as well as indirectly contributing as a result of their influence on vegetation. Exposures of fresh granite occur where stripping has been complete, such as on prominent coastal headlands.

Mobilised granitic material

Slope deposits due to the downslope movement of granitic weathering products consist of a mixture of unconsolidated gravels, sands and clays, with fragments of fresh and weathered granite. They are found flanking the granitic highlands and extending into adjacent valley systems and lowlands. The extensive development of slope deposits at Wilsons Promontory is due to a combination of the steep and dissected terrain, an abundance of weathered material with reduced bulk density and shear strength, a tendency for the area to experience periods of torrential rain, and the susceptibility to removal of the vegetation cover by forest fires (Hill 1992).

Coastal exposures of the slope deposits that mantle the western slopes of Mt Oberon and extend into Little Oberon Bay reveal the internal organisation of these features (Fig. 3). Sorting within the deposits is poor and the structure is generally chaotic but in some parts is subhorizontally bedded sands and gravels. Particle sizes range from clay, silt, sand and gravel size particles to granitic boulders over 10 m in diameter (see Fig. 3). The large boulders are matrix-supported in a framework of silt and clay size particles.

The features of much of these sections are typical of debris flows (Coates 1977; Selley 1988), where the large boulders would have been effectively transported large distances by being supported by the high strength of the matrix. The subhorizontal bedded and channelled units represent periods of fluvial transport, such as in ephemeral stream or sheet flood events. Similar deposits have also been described from other granitic regions throughout the world (e.g. Ruxton & Berry's 1957 work in Hong Kong). The dense colonisation of vegetation, development of pedogenic features, stratigraphic relationship with overlying siliceous sand, and the grading of the fans to a lower sea level indicate that these deposits are no longer active and are probably of Pleistocene age. Similar slope mobilisation, however, still occurs to the present day elsewhere on Wilsons Promontory. This can be seen at the southern end of Waterloo Bay where an approximately 250 m long slope has recently been cleared by a recent debris torrent, and also along sections of the Wilsons Promontory Road south of Darby River.

GEOMORPHIC FEATURES

Drainage and lineaments

A notable feature of the drainage system at Wilsons Promontory is the pronounced linear trend of most of the stream courses (Fig. 4). This type of pattern is typical of granitic areas and reflects joint and fault structures within the granitic bedrock (Hills 1975). Weathering and erosion have been concentrated along many of these structures, resulting in their expression as linear valleys. In some areas of the granitic highlands (such as

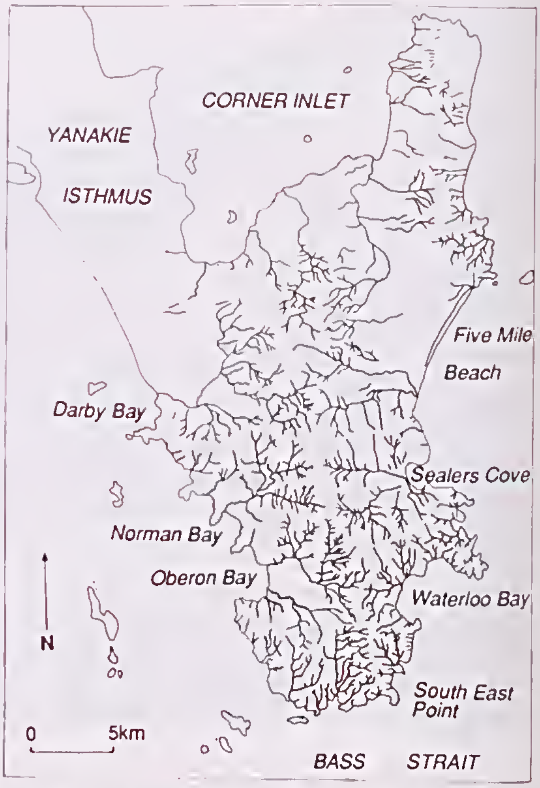


Fig. 4. The drainage system of Wilsons Promontory.

within the Vereker Range) streams have more of a dendritic pattern (Fig. 4). This is considered to be due to deep saprolitic covers which serve to reduce the influence of structures .

Wallis (1981) and Hill (1992) mapped some of the major lineaments in the Wilsons Promontory area (Fig. 5). Fault movements are shown by the displacements of earlier structures and the intrusive sheets of the batholith (Wallis 1981). These movements have also displaced an earlier formed palaeoplain as well as the associated regularly arranged weathering zones. Fault movement has been active from the Cretaceous to the present (Etheridge 1988).

Major northeast–southwest lineaments within the batholith are related to the Early Cretaceous transfer faults of the Bass Basin (Etheridge et al. 1985). Vertical movements along these faults, since the early Cretaceous to the late Tertiary, appear to be responsible for the down-throwing of the Corner Inlet–Yanakie Isthmus area to the north and the area offshore to the south-southeast of Wilsons Promontory.

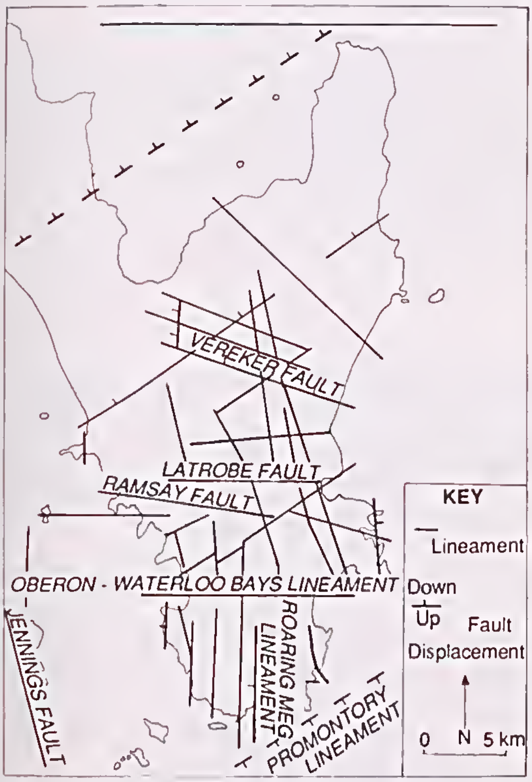


Fig. 5. Major lineaments of Wilsons Promontory, derived from air photograph interpretation field survey and Wallis (1981).

North–south trending faults also appear to have facilitated major vertical movements, in particular along the Jennings Fault west of the Glennie Group of islands (Fig. 5), and along lineaments within the southern and central parts of the main granitic highlands, where upthrown blocks form prominent peaks such as the Boulder Range and Mts Norgate, Wilson, Ramsay and Latrobe (Fig. 7). The development of the valley associated with the north–south Roaring Meg Lineament has diverted an earlier east–west drainage system and deflected it to the south (Fig. 4). These faults are probably related to Cretaceous and Cenozoic reactivation of older Palaeozoic structures.

Palaeosurfaces

Within the steeply sloping and dissected highlands of Wilsons Promontory are high areas of flat to

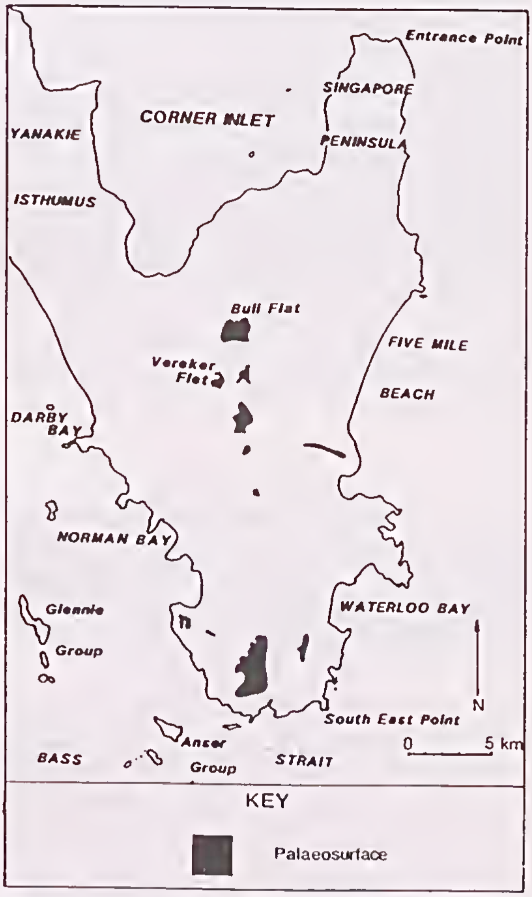


Fig. 6. Palaeosurface distribution at Wilsons Promontory. These areas are characterised by flat to slight slope gradients and deep saprolitic weathering profiles.

slight slopes underlain by saprolite. These features are derived from an ancient landsurface (palaeosurface) that has been preserved in the present landscape. They are mostly confined to the central, inland areas of Wilsons Promontory, or are sheltered between topographic high points (Fig. 6). Erosion has been restricted in these residual areas and allowed the preservation of the surfaces and their deep weathering profiles. In more exposed areas, such as along the coast and at the margins of uplifted fault blocks, much of this deep regolith has been stripped exposing fresh granite.

Major differences in elevation (up to 400 metres) occur between the palaeosurface remnants (Fig. 6). The differences in elevation between localised areas of concordant elevation occurs along the major lineaments shown in Fig. 5. Faulting has apparently displaced a landsurface of lower relief. This palaeosurface has been uplifted most within the central highland area, around Mt Ramsay and Mt Vereker (Figs 6 and 7). The northern part of the batholith between the Yanakie Isthmus and the Singapore Peninsula has subsided relative to these highlands during the formation of the Corner Inlet Basin. Much of this movement appears to have occurred along the Vereker Fault, where cliffs of fresh granite at the northern end of the Vereker Range represents the faultline escarpment. The deeply weathered, subdued terrain to the north of this fault may be associated with a down-faulted part of the ancient palaeosurface.

Tors

Residual boulders of granite, known as tors, are a common landform feature of granitic terrains. They are derived from the stripping of saprolite from weathering zones containing rounded and angular corestones.

A traverse along the centre of the northern spur of Mt Boulder, in the south of Wilsons Promontory, demonstrates a general decrease in tor size and angularity with an increase in altitude (Fig. 8). The lengths of the intermediate axes of 339 tors encountered along a 1500 m long and 50 m wide transect have been plotted against the altitude of the specific tors, determined from a 1:25 000 scale topographic map (Fig. 8A). This is an ideal location to study this relationship because variables that may influence tor morphology (such as the petrographic character of the parent rock, joint pattern and slope mobilisation of tors) are negligible or easily identifiable (Hill 1992). For instance, the slight decreases in tor size trend at 170 and 230 metres above sea level may be accounted for by small zones of closer joint spacing.

The general decrease in tor size and angularity associated with an increase in altitude conforms to the trend found in typical granitic weathering profiles, where the upper portions of the profile contain progressively more weathered corestones which are smaller and more rounded (Fig. 2). The

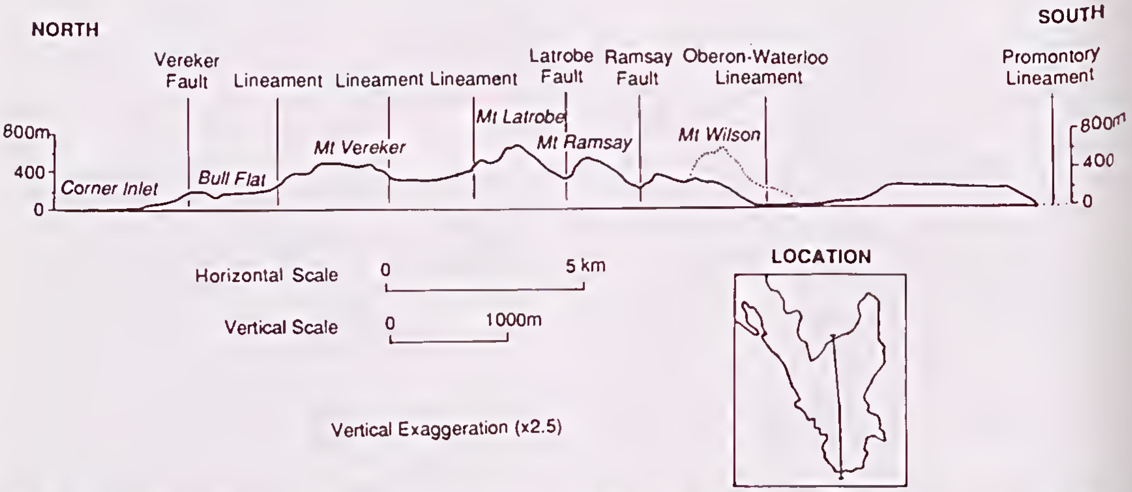
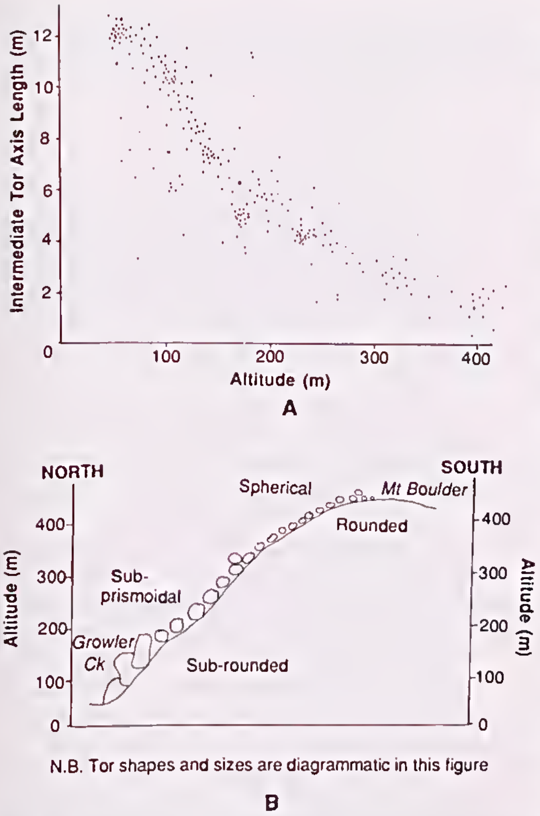


Fig. 7. A north–south cross section across the centre of Wilsons Promontory, with location of major faults and lineaments associated with areas of uplift and subsidence as well as vertical displacement of palaeosurfaces.



N.B. Tor shapes and sizes are diagrammatic in this figure

Fig. 8. Tor features of Mt Boulder, Wilsons Promontory. A. Plotted relationship between intermediate tor axis length and altitude, showing a significant inverse relationship. B. Diagrammatic representation of changes in tor shape with altitude.

occurrence of this relationship between 100 and 400 metres above sea level can therefore be related to the regular arrangement of weathering zones within an extensive, single, stripped weathering profile, that was in excess of 300 m deep.

DISCUSSION: THE DEPTH AND AGE OF WEATHERING

Deep weathering has been a major influence on the landscape evolution of Wilsons Promontory, causing the formation of the granitic regolith materials, as well as many of the associated landforms. Much of the original material has been removed by erosion, making it difficult to assess the extent and age of weathering. The evidence derived from this and previous studies will be discussed here.

Depth of weathering

In many granitic terrain models the surface relief is considered to be a reflection of the depth of stripping of an older deep weathering profile (Linton 1955; Ollier 1983). Stripping of deep weathering profiles in this area has been the major contributor to the development of relief in this area. Analysis of tor morphology suggests weathering in some areas reached depths of at least 300 m. This depth would have varied across the batholith, with even greater depths expected in major joint zones, possibly even approaching the order of the 800 m of relief now found at Wilsons Promontory. There has however been an additional contribution to the relief by tectonic activity. Differential vertical movements of fault blocks has been in the order of hundreds of meters, partly accounting for the relief within the Wilsons Promontory Batholith.

It is interesting to note that no areas of associated extrusive rocks or roof pendant country rock have been found within the batholith. Wallis (1981) considers that the batholith was emplaced at high levels of approximately 1–2 kilometres, with microgranites containing miarolitic cavities which now cap the summits of many peaks representing the near roof zone of the batholith. If this is the case then the overlying 1–2 kilometres of material has been eroded from above the batholith since the Late Devonian. It is likely that much of this material was eroded during the late Palaeozoic, particularly during the Permian when much of this region was covered by large ice sheets (Ollier 1977; Bowen & Thomas 1988). The timing of this erosion is considered further in the following discussion.

The age of weathering

Weathering of the Wilsons Promontory Batholith has occurred during its entire history of exposure to the near surface environment. The development of deep weathering profiles however has depended on periods when the weathering of the bedrock has predominated over the removal of the weathering profile by erosion.

The deep weathering and associated low relief palaeosurfaces most probably post-date Permian glaciation. Further evidence from this region supports this suggestion. Apatite Fission Track Analyses of granites from the Wilsons Promontory Batholith suggest relative tectonic stability between the Permian and mid Cretaceous, followed by uplift and erosion associated with the unconformity at the top of the Early Cretaceous Strzelecki Group within the Gippsland Basin (Duddy & Green 1992).

During this Mesozoic tectonic stability, conditions would have been suitable for the development of deep weathering profiles, as was the case in many other parts of southeastern Australia (Hills 1975; Jenkins 1988; Bird & Chivas 1989).

The onset of erosion in the mid Cretaceous is recorded in the sedimentary record in the Gippsland Basin, where there is a transition from the volcaniclastic Strzelecki Group to the detrital Latrobe Group. The Late Cretaceous to Oligocene Latrobe Group sediments represent terrigenous material derived from the margins of the Gippsland Basin, such as Wilsons Promontory (Lowry & Longley 1991). The dominance of quartz in these sediments is largely due to stripping of deeply weathered granites, such as at Wilsons Promontory, where there has been a relative accumulation of these stable minerals. Further evidence for Tertiary stripping of a deeply weathered terrain is shown by Eocene gravels in the Toora region north of Wilsons Promontory. These sediments contain an abundance of resistant minerals such as quartz, tourmaline and cassiterite, derived from the Wilsons Promontory granites (Spencer-Jones 1955). Labile minerals and clasts of fresh granite are absent from the sediments derived from the batholith area until late in the Cenozoic when they are included in slope deposits and Quaternary sands (Hill 1992). The sedimentation since the mid Cretaceous and through the Cenozoic therefore represents the progressive stripping of a deep weathering profile. Earlier derived sediments represent saprolitic materials with later contributions coming from less weathered zones in the profile as stripping extended to these depths.

The period before the mid Cretaceous is therefore likely to have been associated with the development of deep weathering profiles, and so the associated palaeosurfaces on which the profiles developed must be older. This palaeosurface is probably related to the Trias–Jura palaeoplain described by Hills (1975) in southeastern Australia. The onlapping of early Cretaceous Strzelecki Group sediments over granitic unconformity surfaces offshore of Wilsons Promontory and further west at Cape Woolami on Phillip Island adds further supports this age of the paleaosurface in this region. Tectonic instability since the mid Cretaceous has led to an increase in erosion, with the stripping of the deep weathering profiles in all but some central or protected areas within the main highlands. Further weathering of the granites would no doubt have occurred through the Tertiary to the present, but this is of less significance than the high rate of erosion that has occurred during these times. The minor Cenozoic weathering is Represented by the profiles developed on the Cretaceous Strzelecki Group volcanoclastics within the South Gippsland Highlands to the north of Wilsons Promontory.

SUMMARY

The stages of landscape evolution

1. Deep weathering, probably during the Mesozoic, after the widespread glacial erosion during the Permian. The dominance of deep weathering versus erosion would have been facilitated by a relatively stable landscape of subdued relief.
2. Faulting and uplift of the Wilsons Promontory Batholith in the mid Cretaceous resulted in erosion of the deep weathering profiles. The eroded weathered material was transported into the Gippsland Basin and contributed to the detrital Latrobe Group sediments.
3. Predominance of erosive stripping of the granitic regolith in the mid to late Tertiary with a minor continuation of weathering. Stripping, particularly of upthrown blocks, occurred by stream dissection with downslope movement of regolith, on fault blocks. Deep regolith profiles remain in areas with greater preservation potential such as downthrown blocks.
4. Late Cenozoic deposition of quartz sands, largely derived from granite regolith material, around the coastal margins of the batholith. The Yanakie Isthmus formed as a tombolo, joining the granitic highlands to the mainland.
5. Deposition of calcareous sands derived from carbonate reefs to the west, during the Pleistocene and Holocene. These sands have been reworked into large easterly transgressing dunes since the Pleistocene.
6. Continued stripping of granitic regolith to the present, particularly along coastal margins, with less significant weathering. Deposition of siliceous sands along the east coast and calcareous sands along the west coast. Alluvial outwash and swamp deposition in low lying areas.

CONCLUSIONS

Wilsons Promontory is an area of Devonian granite. The evolution of the present Wilsons Promontory landscape began after the granite was exposed, presumably by the glacial erosion of the Permian. Since that time the granites of the Wilsons Promontory Batholith have been exposed to near surface conditions where they have been deeply weathered. In the Mesozoic a palaeoplain existed and weathering predominated over erosion. The resulting deep weathering profiles extended to depths in excess of 300 metres. Tectonic instability in the early Cretaceous instigated stripping of the deep weathering profiles, contributing sedimentary material to adjacent areas such as the Gippsland Basin. Remnants of the deep weathering profiles that began their development during the Mesozoic owe their present survival to areas where the influence of erosion has been limited, such as down-faulted blocks and the interior and sheltered parts of the highland areas.

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